

## **Acoustically-equipped Ocean Gliders for Environmental and Oceanographic Research**

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Award Number: N00014-13-1-0682  
<http://www.bioacoustics.us>

### **LONG-TERM GOALS**

The long-term goal of this project is to establish acoustically-equipped gliders for use in research on marine mammal occurrence and behavior. The instruments purchased with this grant will significantly enhance our DoD-funded work, including both currently-funded research and proposed research.

### **OBJECTIVES**

The Navy observes and studies marine mammals, both to better understand marine mammal occurrence and behavior and also to mitigate the deleterious effects of its operations on marine mammals. To facilitate acquisition of marine mammal data, we will purchase two gliders for passive-acoustic marine mammal observation and research. Since 2008 we have been collaborating with the Applied Physics Laboratory at the University of Washington (APL-UW) to develop, test, and use Seagliders™ (owned by UW) equipped with passive acoustic sensors and recording system. This system has been successfully deployed many times now, and we propose to purchase two of these acoustically-equipped gliders for enhancing our DoD-funded research. Enhancement will come in the several areas: (1) marine mammal acoustic research and monitoring from gliders, for which these new gliders will allow us to operate glider missions more often and accelerate the research cycle; (2) marine mammal density estimation research, for which these new gliders will allow us to gather more data, test and calibrate methods, and better develop glider-specific density estimation methods; (3) detection, classification, and localization (DCL) research, for which these new gliders will allow collection of much more data, create a faster cycle time for developing DCL algorithms, and develop better glider-specific DCL methods; (4) acoustic propagation research, for which these new gliders will allow us to collect environmental data key to measuring sound speed (temperature, salinity) simultaneously with collection of acoustic data to measure propagation, and collect such data repeatedly over an extensive geographic area; (5) ocean noise research; (6) ecosystem process research, for which these new gliders will allow us to observe high-trophic-level marine mammals in conjunction with other parameters, and enable collaboration with researchers studying other physical and biological processes; and (7) research and monitoring on Navy ranges.

## APPROACH

Ocean gliders equipped with passive acoustic systems provide a low-cost means to study marine mammals and related oceanic processes. They can be used for long-duration, large-area surveys to determine when and where different species are present. They can simultaneously sample physical properties such as temperature, salinity, dissolved oxygen, and nutrients, as well as estimating currents by comparing glider movements expected from direction and speed measurements and the actual movements as measured by GPS positions. These observations enable greater understanding of the factors driving marine mammal occurrence and populations.

Acoustically-equipped gliders can also be used to mitigate possible harm to the mammals. They could also form a component of a near-real-time detection and reporting system to warn naval operators, including sonar operators and leaders of exercises employing explosives, of the presence of cetacean species of interest so they could take appropriate steps to mitigate potential harm. This is possible because gliders, unlike autonomous hydrophones moored on the seafloor, are capable of near-real-time response to signals detected from marine mammals. This requires, of course, a glider-resident detection/classification system that is capable of knowing when any species of interest are present. We have been working for years on such a system, and have successfully deployed it to detect beaked whale species of interest from a glider.

Acoustically-equipped gliders for marine mammal research (Fig. 1) could also be used to evaluate any potential impacts of Navy activities (sonar, use of explosives, multiple-ship presence, etc.), or other human activities in the ocean such as shipping, on marine mammals exposed to these activities. Because gliders can persist for months at a time, they are well-suited for experiments that measure marine mammal occurrence and acoustic behavior before, during, and after exposure.

We have been collaborating since 2008 with Neil Bogue and Jim Luby of the Applied Physics Laboratory, University of Washington (APL-UW) to develop and use acoustically-equipped gliders for marine mammal research. We have developed a system for sensing and recording ocean sound and detecting marine mammal vocalizations in it. Via the glider's satellite communications system, the glider can report such detections in near-real time – within minutes to a few hours – after the animal produces them. Also using this satellite communications system, we can also respond immediately to detections by changing the glider's mission if desired. For example, if during a wide-area survey an unusual species of beaked whale is found, the glider can be reprogrammed to remain on station and determine how long that species remains present, as well as recording its acoustic behavior and hence its foraging behavior.

During this collaboration, we have had successful deployments of two acoustically-equipped gliders to detect and study cetaceans in the Puget Sound area, at the Navy's AUTEC range in the Bahamas, off the Kona coast of Hawai'i (Klinck *et al.*, 2012), and off the coast of Washington and Oregon. These two gliders are owned and operated by APL-UW.



*Fig. 1. A Seaglider™ equipped for passive acoustics*

## WORK COMPLETED

Two Seagliders, numbers SG607 and SG608, were purchased from Kongsberg, Inc. (Lynnwood, WA) and were delivered to OSU in September 2014. A reliable communication link between the two Seagliders and OSU's Iridium base station was established in fall 2014. APL-UW completed the revisions of the passive acoustic monitoring (PAM) boards and installed them on the gliders. The modified PAM board now features 8 microSD memory card slots providing a total of approximately 512 GB of data storage (~1 TB with FLAC audio compression enabled).

Glider SG607 was successfully tested off Newport, OR in March 2015. SG607 was then deployed on the Quinault Training Range (QTR) off the coast of Washington state in March 2015 as part of a project (LMR contract #N39430-14-C-1435) to study the ability to detect cetaceans among different acoustic recording platforms. The glider and its recording system worked as planned.

Both gliders SG607 and SG608 were again tested off Newport, OR in May 2015. SG608 functioned as planned, but SG607 had some problems communicating with the base station and required a bit of searching to recover. After retrieval, it was determined that the communications antenna was slightly faulty; this antenna was replaced by the manufacturer in June 2015, and the glider now appears to be fully functioning.

After its May test, SG608 was deployed in the northern Gulf of Mexico in late June 2015 as part of an industry-funded project to study the impact of the Deepwater Horizon disaster on the occurrence of cetaceans (sperm whales, beaked whales, dolphins) in that area. Most unfortunately, during recovery of this glider in early August 2015, the hull of the recovery vessel struck the glider and it (the glider) was lost. The recovery team searched for the glider for many hours without success. SG608 was never seen again, nor did it again communicate with its base station.

The glider, including its acoustic system, was partially (~80%) insured; as of this writing (Sept. 2015), the insurance claim is being processed by OSU's insurance company. Assuming the insurance claim is paid, we plan to purchase another Seaglider and outfit it with an acoustic system. In the meantime we are using a Seaglider which was lent to us by the OSU College of Oceanic and Atmospheric Sciences.

## RESULTS

SG607 and SG608 were successfully equipped with acoustic systems and successfully deployed, in Washington and Louisiana respectively. SG607 was recovered and was found to have operated well; SG608 was lost during recovery and is being replaced.

## IMPACT/APPLICATIONS

The U.S. Navy's operations, including use of tactical sonars, have been linked to marine mammal strandings and fatalities (Barlow and Gisiner, 2006), particularly of beaked whales, which appear to be particularly sensitive to mid-frequency sonars. These events have generated legal challenges to the Navy's peacetime use of mid-frequency sonar, and have limited the Navy's at sea anti-submarine warfare training time. A mobile, persistent system that can detect, classify, and localize marine mammal species of interest can help resolve the conflict between the Navy's need for realistic training of sonar operators and the Navy's desire to protect the marine environment, especially marine mammal populations, worldwide.

Furthermore, a system capable of simultaneously monitoring other aspects of the marine environment will allow better understanding of marine mammal occurrence, populations, and movements. As for any organism, occurrence of marine mammals is closely linked to the availability of food resources (e.g., Baumgartner *et al.*, 2003) and the presence of predators, and food resources are linked to physical and biological ocean processes (e.g., Tynan *et al.*, 2005). By simultaneously observing multiple levels of these processes, an integrated view of the factors driving marine mammal occurrence may be achieved (e.g., Croll *et al.*, 2005).

## RELATED PROJECTS

We have been collaborating with Neil Bogue and Jim Luby of the Applied Physics Laboratory, University of Washington (APL-UW) for development and use of gliders for research on marine mammals (N000141010387). APL-UW owns the three acoustically-equipped Seagliders that have been used in this collaboration. Our purchase of two additional gliders will strengthen this line of research in several ways:

- We will be able to deploy the gliders more often for marine mammal monitoring. In the past we have sometimes been limited by the availability of APL-UW personnel to do projects; marine

mammal monitoring is only a small component of their work, and finding times when they are available can be difficult.

- When we collaborate with APL-UW, we would have a total of five gliders, allowing us to cover larger areas, or cover the same areas at greater glider density. This will enhance our ability to research marine mammals through acoustics.
- When we collaborate, we could extend our mission time to have two gliders operating essentially indefinitely. We would do this by deploying two refurbished gliders each time we recover two other gliders at the end of their deployment. This will allow us to investigate the use of gliders for acoustic study of marine mammals over much longer time scales and, potentially, larger areas than we can at present. Without collaborating, we can keep only one glider deployed indefinitely in the same manner.

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